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Longitudinal asymmetry in the time of peak occurrence in NmF2 between the Asian and South American low latitude sectors

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Abstract : A time delay in the occurrence of the daytime peak in F region ionization between the solstices was observed in the Asian Pacific and South American 'equatorial anomaly' region. The time delay was found to be independent of solar activity conditions. On an average, the time delay of about an hour, was from winter to summer in the northern hemisphere and from summer to winter in the southern hemisphere indicating a longitudinal asymmetry between the Asian and American sectors.

Keywords : NmF2, equatorial anomaly, $\tilde{E} \times \tilde{B}$ drift

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1. Introduction

The peak density of the ionospheric $F2$ region (NmF2) shows a steady increase from sunrise to a couple of hours beyond local noon followed by a gradual fall till midnight. The most well known feature of low latitude NmF2 is the formation of a trough at the equator and crests at about ± 30° magnetic dip, known as the 'equatorial' or 'Appleton' anomaly [1]. The anomaly is caused by the so-called 'fountain' effect due to which ionization over the equator is lifted to higher altitude by $\tilde{E} \times \tilde{B}$ vertical drifts and then diffused along the magnetic field lines to form the maximum in ionization at tropical latitudes [2]. Variations in the structure of the 'equatorial anomaly' in different longitude sectors are well known [3]. Theoretical investigation of the effect of longitudinal changes in geomagnetic field configurations, neutral winds and $\tilde{E} \times \tilde{B}$ drifts, shows that the longitudinal differences were mainly due to differences in $\tilde{E} \times \tilde{B}$ characteristics.

In this communication, we investigate the seasonal variations of the time of occurrence of diurnal maximum of NmF2 in the Asian Pacific and South American longitude sectors.

2. Data

foF2 data used in this analysis were obtained at Chungli (25°N, 121°E geographic; mag. dip 25°N), Taiwan in the Pacific and at Sao Paulo, Brazil (24°S, 47°W geographic; magnetic dip 22°S) and at Tucuman, Argentina (27°S, 65°W geographic; mag. dip 22°S) in South America. The selected stations almost identically located with respect to the geomagnetic equator in the northern (Chungli) and southern hemispheres (Tucuman and Sau Paulo) normally lie within the crest region of the 'equatorial anomaly' in respective hemispheres. Data for Chungli covers a period of seven years from 1977 to 1983 while for the South American stations, the data covers another period of equal length from 1957 to 1963 including that of the IGY. The foF2 data were converted to NmF2 by using the formula

$$NmF2 = 1.24 \times (foF2)^2. \tag{1}$$

3. Results

In Figure 1, the seasonal average NmF2 are plotted as a function of local time for Chungli for the years 1977 to 1983. The respective solar activity levels in terms of mean 10.7 cm solar

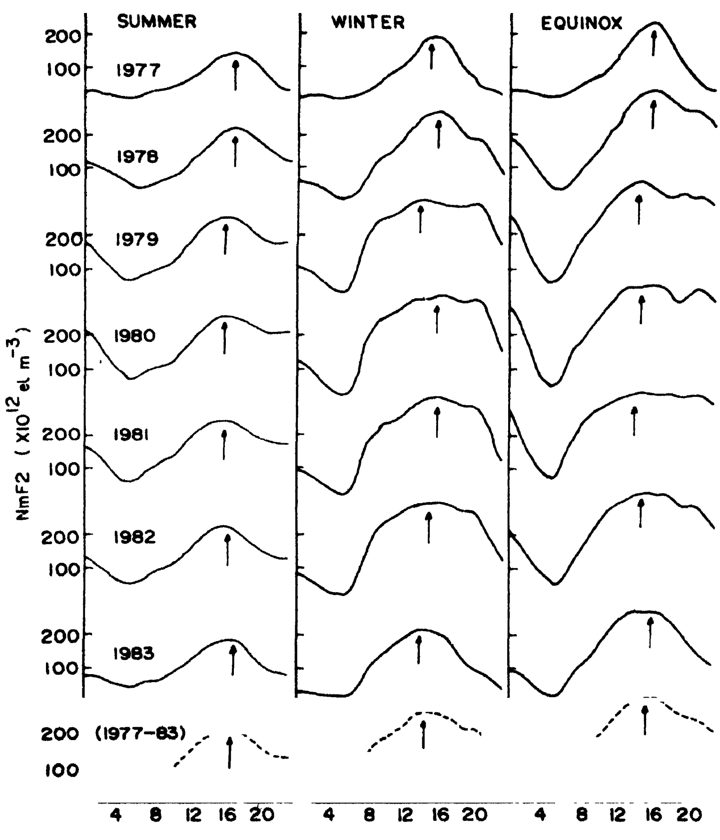

Figure 1. Average NmF2 plotted as a function of local time for Chungli, Taiwan. The arrow heads indicate the time at which peak NmF2 was observed.

flux are given in Table 1. The arrow heads in the figure indicate the hour at which NmF2 reached its maximum daytime level. It could be seen that the diurnal peak occurs earlier in winter (between 14–16 hr LT) and later in summer (at around 16–17 hr LT) in all years of observation. The winter to summer time delay varies between a maximum of 2.5 hours in 1983 to a minimum of 0.5 hour in 1980. The times of occurrence of the diurnal maximum in respective seasons and years are also given in Table 1 for all the three stations. The seasonal averages for the whole period shows that in winter, the diurnal peak was advanced by an hour (15 hr LT) compared to that in summer (16 hr LT) at Chungli.

Figures 2 and 3 show NmF2 similarly plotted for the South American stations, Tucuman and Sao Paulo respectively. Diurnal variations of NmF2 for Tucuman illustrated in Figure 2, show that the general features are similar to that seen at Chungli. The maximum in

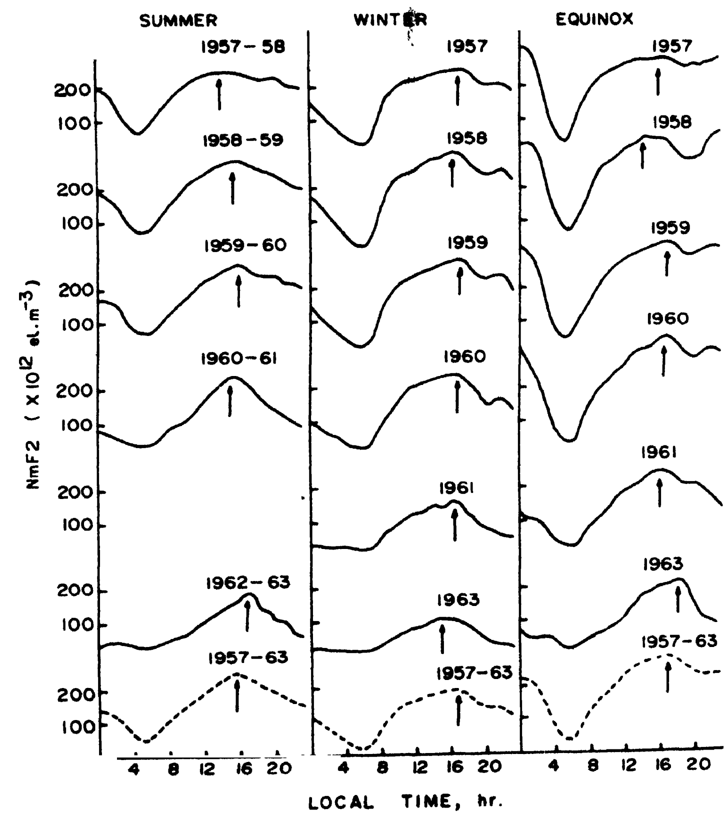

Figure 2. As in Figure 1 for Tucuman, Argentina.

ionization which occurs between 14–16 hr LT has seasonal as well as year to year variation. It may be noted that both at Tucuman and Sao Paulo (Figure 3), the daytime maximum in ionization occurs earlier in summer than in winter. The summer peaks occur around 15 hr LT (1510 hr LT for Sao Paulo and 1520 hr LT for Tucuman, Table 1) while in winter the average time of occurrence of the diurnal peak was found to be 1610 hr LT for both the stations.

Table 1. Average times of occurrence of the diurnal peak in NmF2 and mean 10.7 cm solar flux.

Chungli						Sao Paulo						Tucuman					
Summer		Winter		Equinox		Summer		Winter		Equinox		Summer		Winter		Equinox	
S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T
84	1700	89	1500	88	1600	249	1400	220	1700	236	1800	249	1400	220	1600	236	1600
134	1700	147	1600	154	1630	229	1530	225	1630	241	1700	229	1500	225	1600	241	1400
171	1600	210	1400	194	1500	183	1530	217	1700	199	1300	183	1530	217	1700	199	1730
192	1600	212	1600	191	1600	127	1500	166	1700	154	1800	127	1500	166	1600	154	1630
191	1600	199	1600	218	1630	94	1530	108	1600	104	1600	-	-	108	1600	104	1630
161	1600	190	1500	175	1500	80	1500	87	1500	93	1630	80	1700	87	1600	93	1700
131	1630	113	1400	115	1600	-	-	102	1500	81	1800	-	-	-	-	81	1800

S represents mean $S_{10.7}$ cm solar flux, T represents local time of diurnal maximum in hours.

Thus, we have seen a reversal of the seasonal time delay in the occurrence of the daytime peak in NmF2 in the South American longitude sector compared to that in the East Pacific longitude sector.

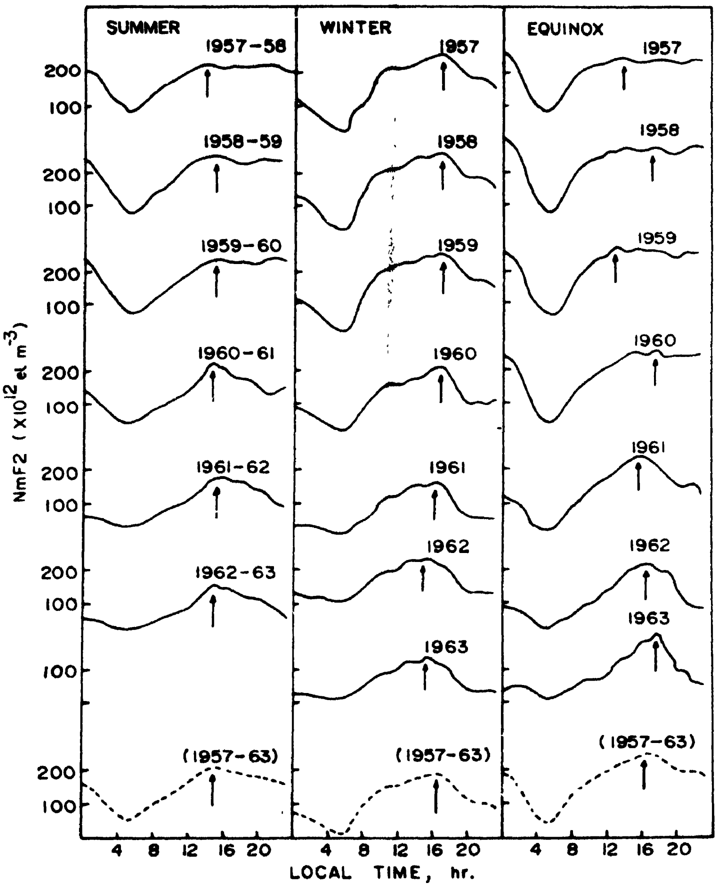

Figure 3. Same as in Figures 1 and 2 for Sao Paulo, Brazil.

In a recent communication [4], we had investigated the times of occurrence of the daytime maximum in ionospheric electron content (IEC) at a number of Indian stations for the solar minimum period 1975–76. Seven of the stations used in that analysis form a latitudinal chain along 71(±2)°E meridian extending from the dip equator (0.5°N dip latitude) to well beyond the crest of the equatorial anomaly (20°N dip latitude). It was observed that the peak occurs earlier in winter and later in summer at all the locations. The winter to summer time delay was found to have latitudinal variation increasing from a minimum near ~9°N dip latitude towards higher and equatorial latitudes. It was also observed that this variation with latitude was not caused by random variations in the peak occurrence. In summer, the maximum was observed at about the same local time (15 ± 0.5 hr) whereas the same in winter varied from place to place. The observed seasonal variation in the time of peak occurrence was shown to be annual and independent of solar activity conditions.

It could be seen from Table 1 that the mean solar flux varied from a maximum of S = 249 to a minimum of S = 80 during 1957–1963 while in the 1977–1983 period, the maximum and minimum for solar flux was 212 and 84 respectively. The times of occurrence of the diurnal maximum as seen from the table, bear no correlation with solar flux either at Chungli or at Tucuman or Sau Paulo. Similarly, the time delay is only annual in nature.

4. Discussion

The dominant mechanism controlling the F region ionization at equatorial and low latitudes is the $\tilde{E} \times \tilde{B}$ drifts. Diurnal and seasonal variations in F region drifts over Jicamarca, Peru (12°S, 77°W; mag. dip 2°N) have been reported by Woodman *et al* [5] and Fejer *et al* [6]. When the daytime maxima in F region vertical drifts were compared, a time difference of more than 1 hour from summer (1000 hr LT) to winter (1100 hr LT) was observed. This was further confirmed from reported [7] foF2 observations at Huancayo, Peru (12°S, 75°W; mag. dip. 2°N). The foF2 over Huancayo peaks at about 1530 hr LT in summer and at 1730 hr LT in winter. These observations coupled with that reported in the present analysis show that there is a time delay in the occurrence of the daytime peak in F region ionization between the solstices at low and equatorial latitudes. The delay is from winter to summer in the northern hemisphere and from summer to winter in the southern hemisphere.

Fejer [8] had shown that the vertical drift reversal times in the Peruvian and Indian equatorial regions have similar annual variation with a six month shift between the two. The magnetic equator lies ~9°N of the geographic equator in the Asian region (120°E) while it is ~12°S of the geographic equator in the American region (75°W). The reason for the half-yearly shift in the vertical drift reversal times, was believed to be the location of the Peruvian and Indian stations in the southern and northern hemispheres respectively. It may be worthwhile to look for a mechanism coupled to the EEJ and responsible for this spatial shift. The EEJ and Sq current systems are coupled interactive systems [9]. The mean daytime Sq foci are asymmetric about the dip equator and the total intensities of the external Sq current system vary with seasons [10–12]. The EEJ resulting out of the asymmetric current system do not always flow parallel to the dip equator, particularly, during winter and summer and thus, cumulative effect of the EEJ might be to produce seasonal variation in the magnitude of the vertical drift velocities and consequently to produce seasonal variations in the ionization structure at low latitudes. Walker [3] had observed that the longitudinal difference in equatorial anomaly structure between the Asian and American sectors, might be due to the different location of the sub-solar points with respect to the magnetic equator. The sub-solar point averaged over summer is nearer the magnetic equator in the American zone (~5° dip lat) than in the Asian zone, where it lies near the tropics (~13° dip lat) *i.e.* nearer to the anomaly crest region.

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